

Reflective multi-layer etching for repairing clear defect on EUV masks using FIB

Tsuyoshi Amano, Noriaki Takagi, Hiroyuki Shigemura,
Tsuneo Terasawa, Osamu Suga

MIRAI-Semiconductor Leading Edge Technologies, Inc. (Japan)

Tomokazu Kozakai, Fumio Aramaki, Anto Yasaka

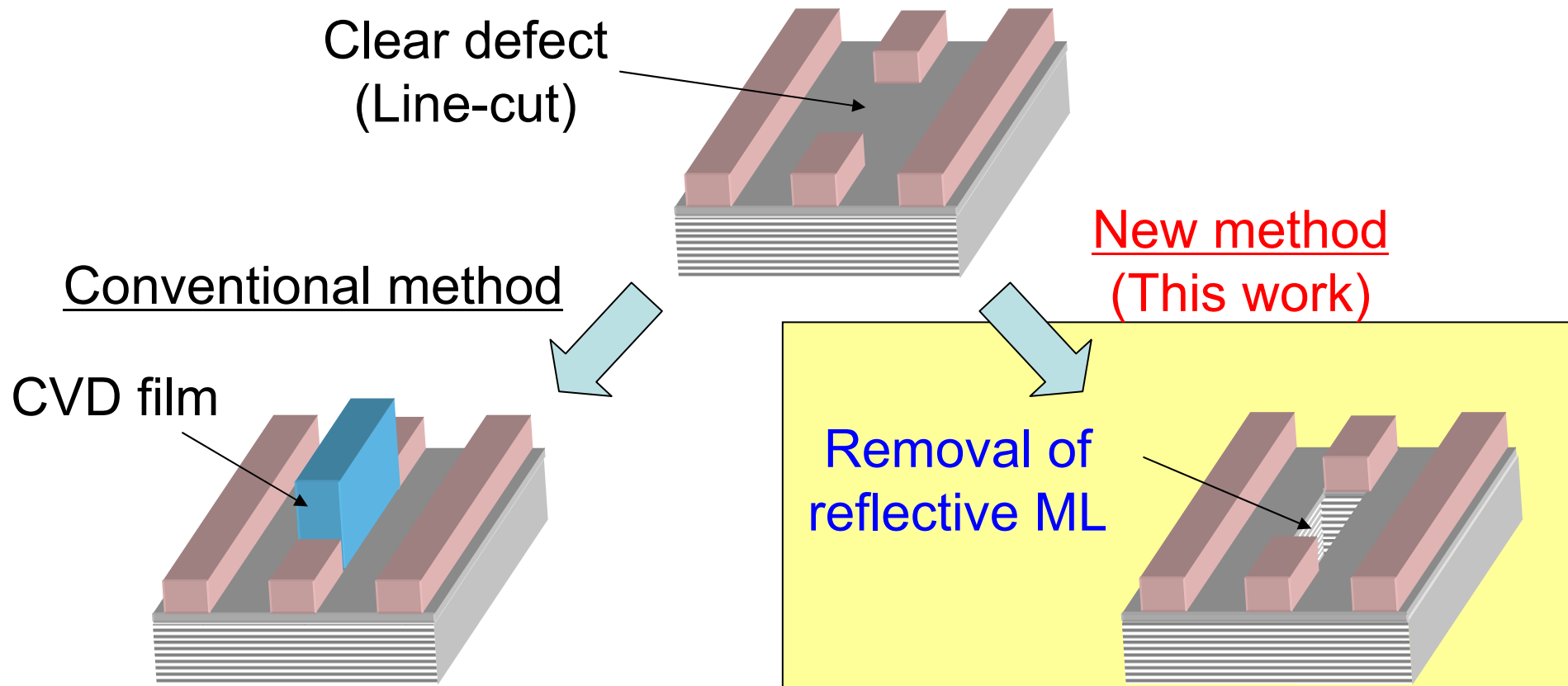
SII NanoTechnology Inc. (Japan)

Yuuichi Inazuki, Naoya Hayashi

Dai Nippon Printing Co., Ltd. (Japan)



Semiconductor Leading Edge Technologies, Inc.



Issues of conventional process of forming CVD films are:

Lack of the EUV-light shielding capability.

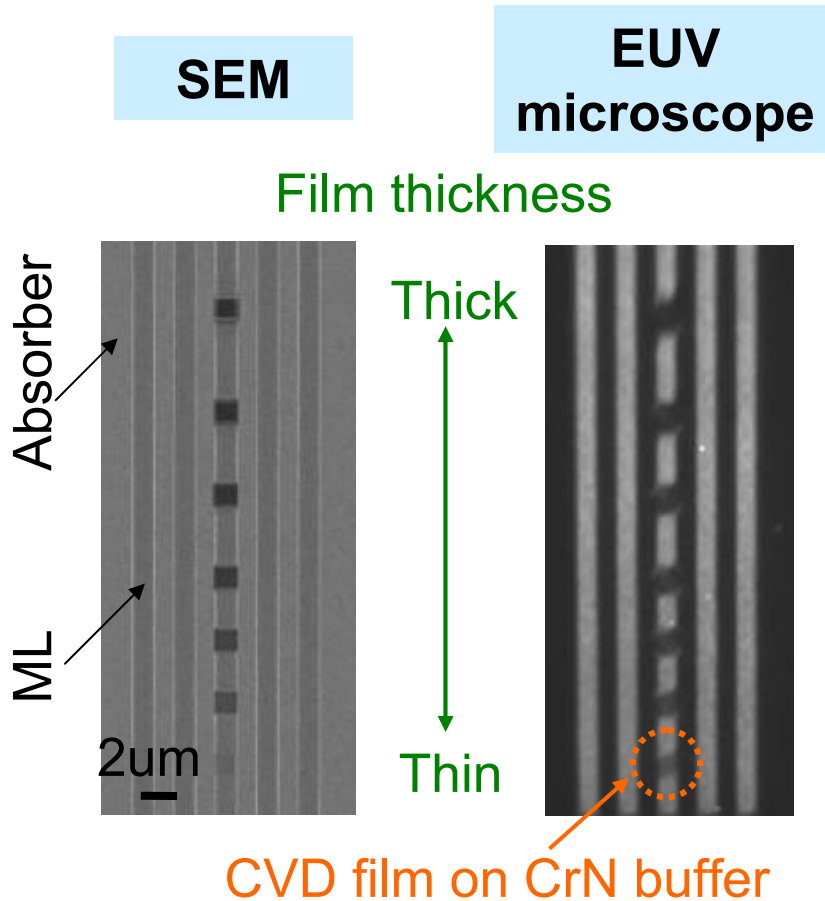
=> Thick film will cause large shadowing effect.

Lack of the cleaning selectivity over contamination.

=> Wafer printability will be changed.

Calculated film thicknesses which have the same light shielding capability with the 51nm thick of absorber layer

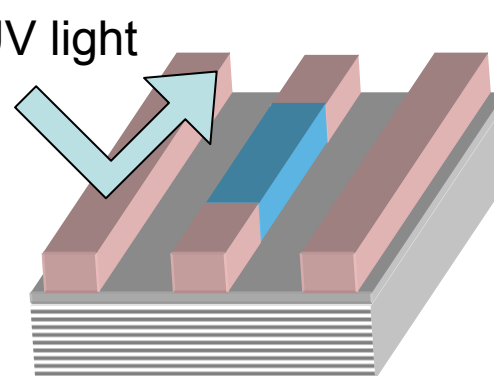
	C	W	Si
FIB-CVD	183 nm	59	74
EB-CVD	> 200	117	125



Ideal thickness for lithography

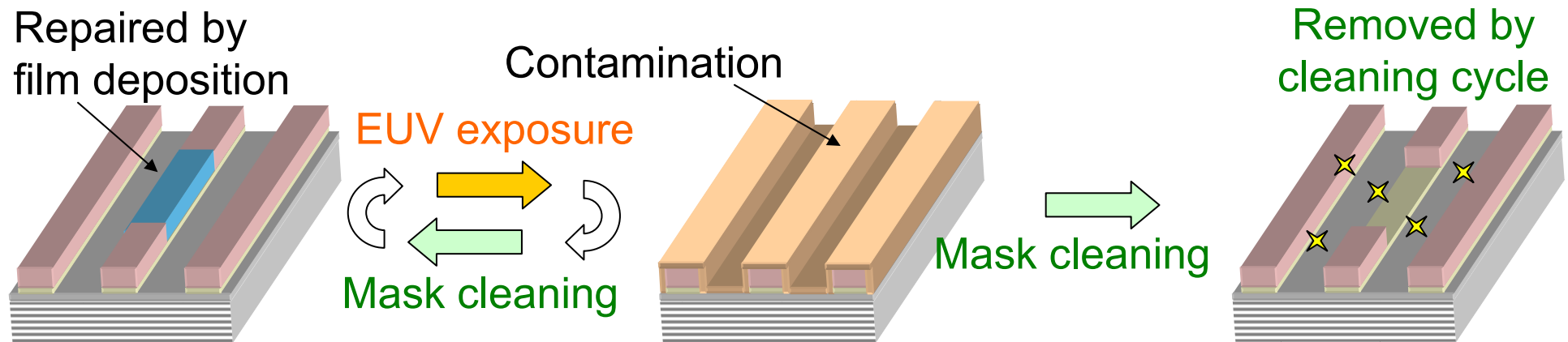
Too thick film causes large shadowing effect

EUV light



Thicker CVD film than the absorber layer is required.

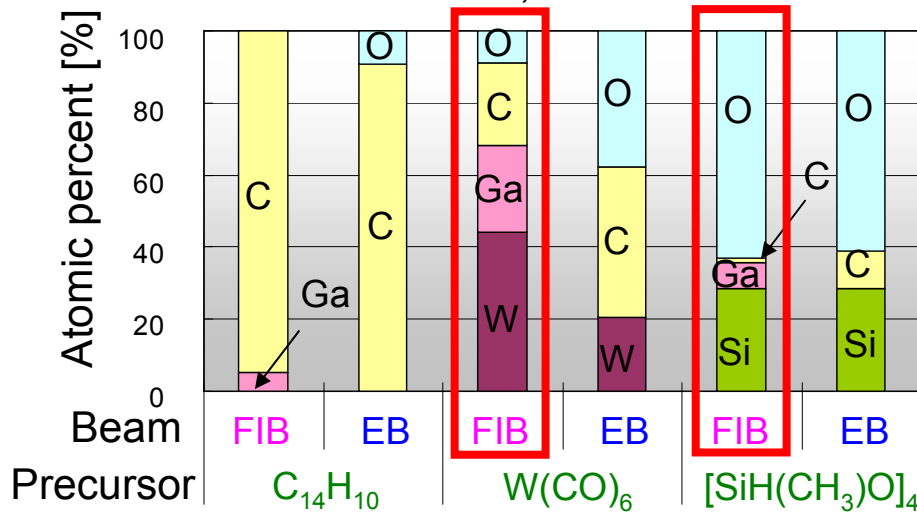
Contamination cleaning cycle during high volume chip manufacturing



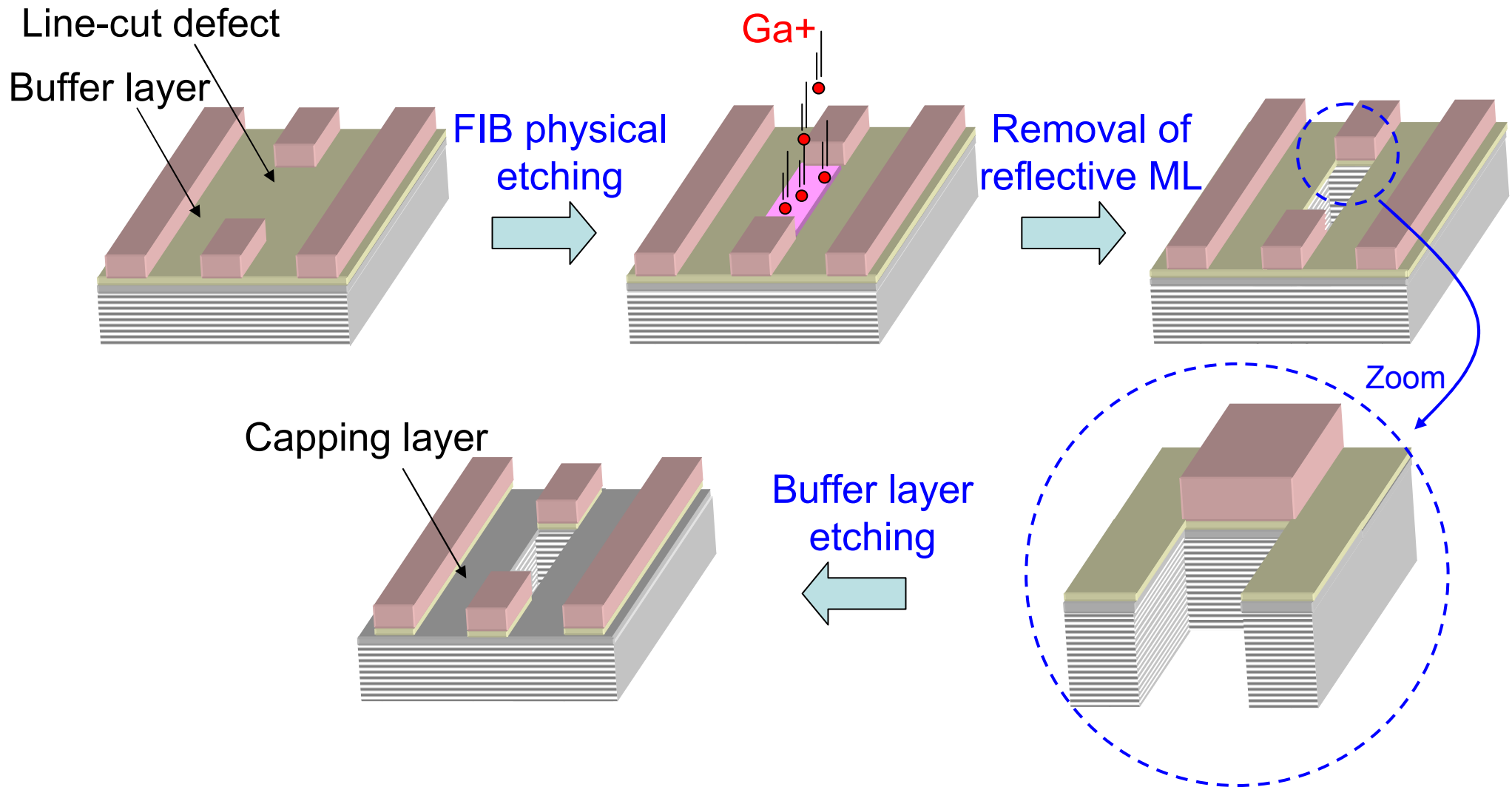
CVD films are required extremely high cleaning selectivity.

EDX analysis of CVDed films

FIB: 15kV, EB: 3keV



W or Si based FIB-CVD films did not loss the thicknesses against three types of dry cleaning process (VUV, Pure O_3 and H-radical).



Repair tool and condition

Tool:	SIR-7 (SII NanoTechnology Inc.) for 65 and 45 nm node
Ion:	Ga ion
Vacc:	15 kV
Etching gas:	none



Exposure tool and condition

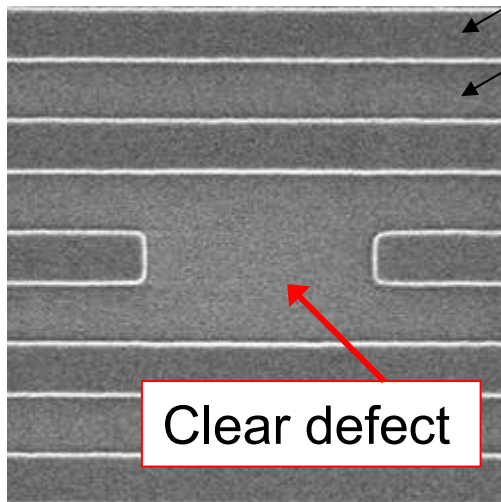
Tool:	SFET*
Exposure optics:	NA: 0.3 (central obscuration 30%) Sigma (inner/outer): 0.3/ 0.7 Magnification: 1/ 5 Incident angle: 6 deg.
Resist:	SSR4**

* SFET: Small Field Exposure Tool

** Selete Standard Resist 4

Pre repair

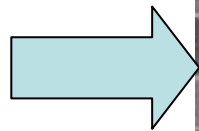
hp225nm L/S



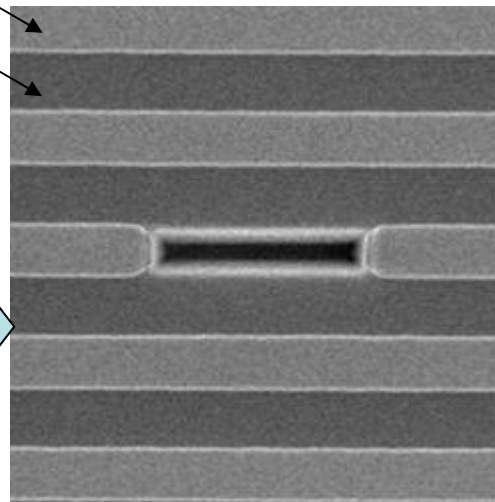
Absorber

Cr-buf.

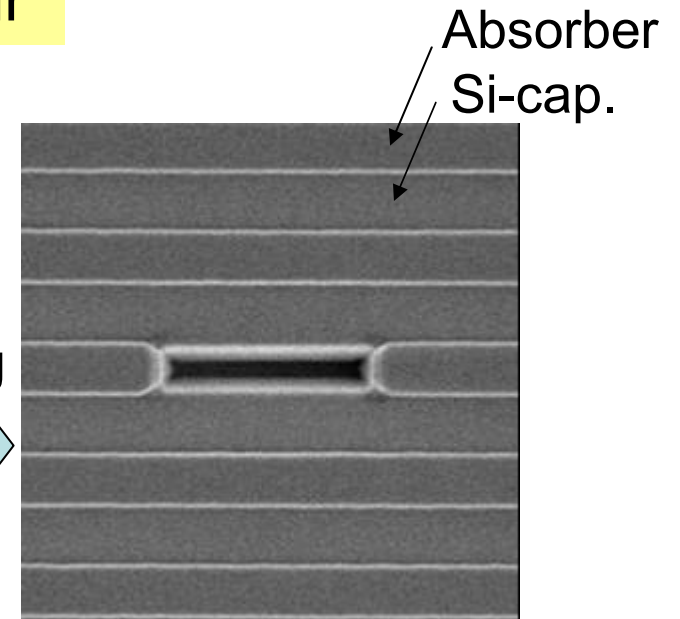
repair



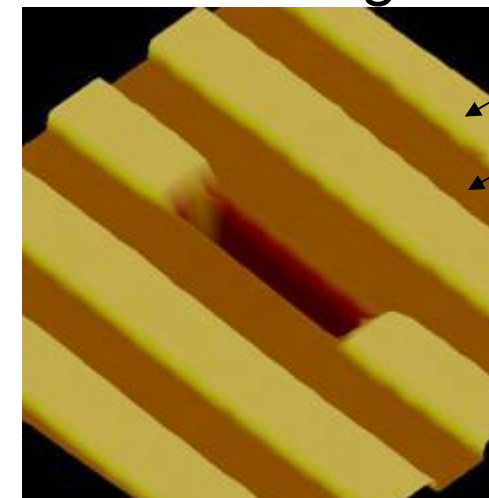
Post repair



Buffer
etching



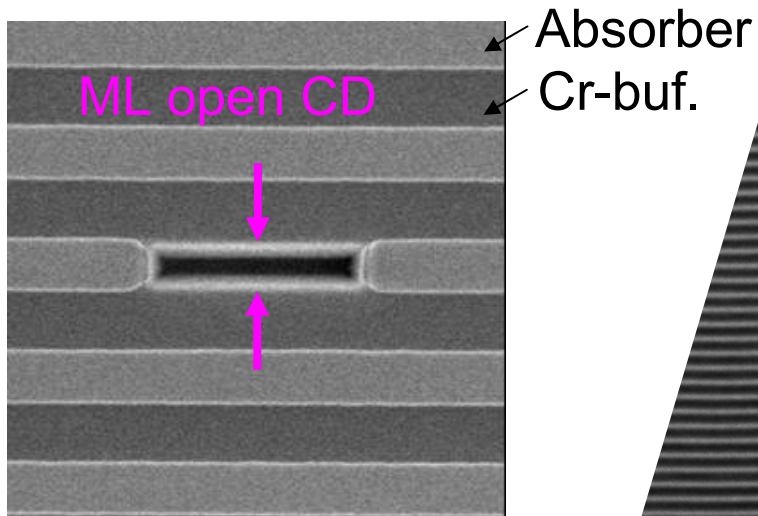
AFM image



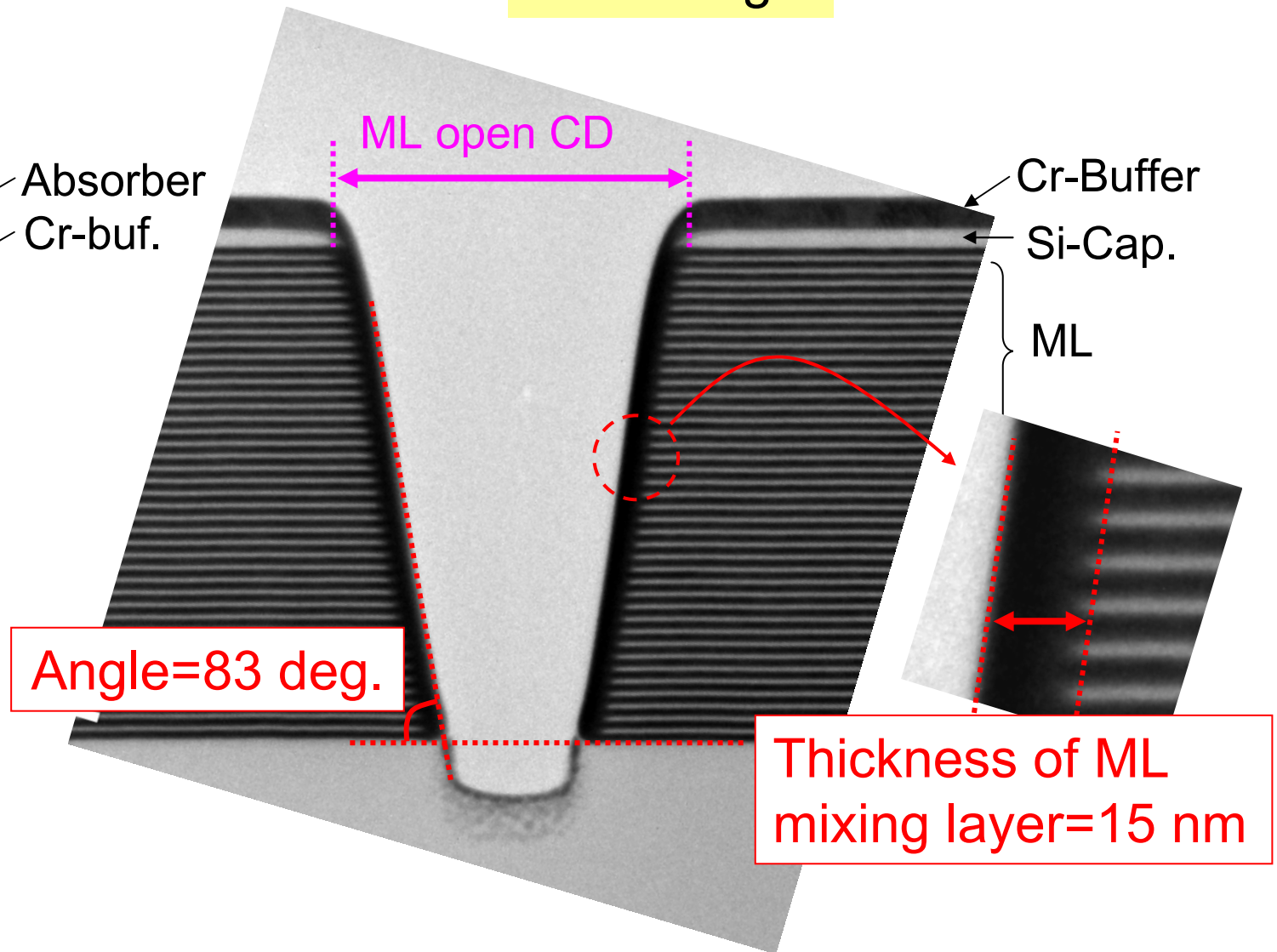
- The repair process performed well.
- The etched ML did not show any obvious size change after buffer etching.
- No buffer residue was observed on the Si-cap. layer.

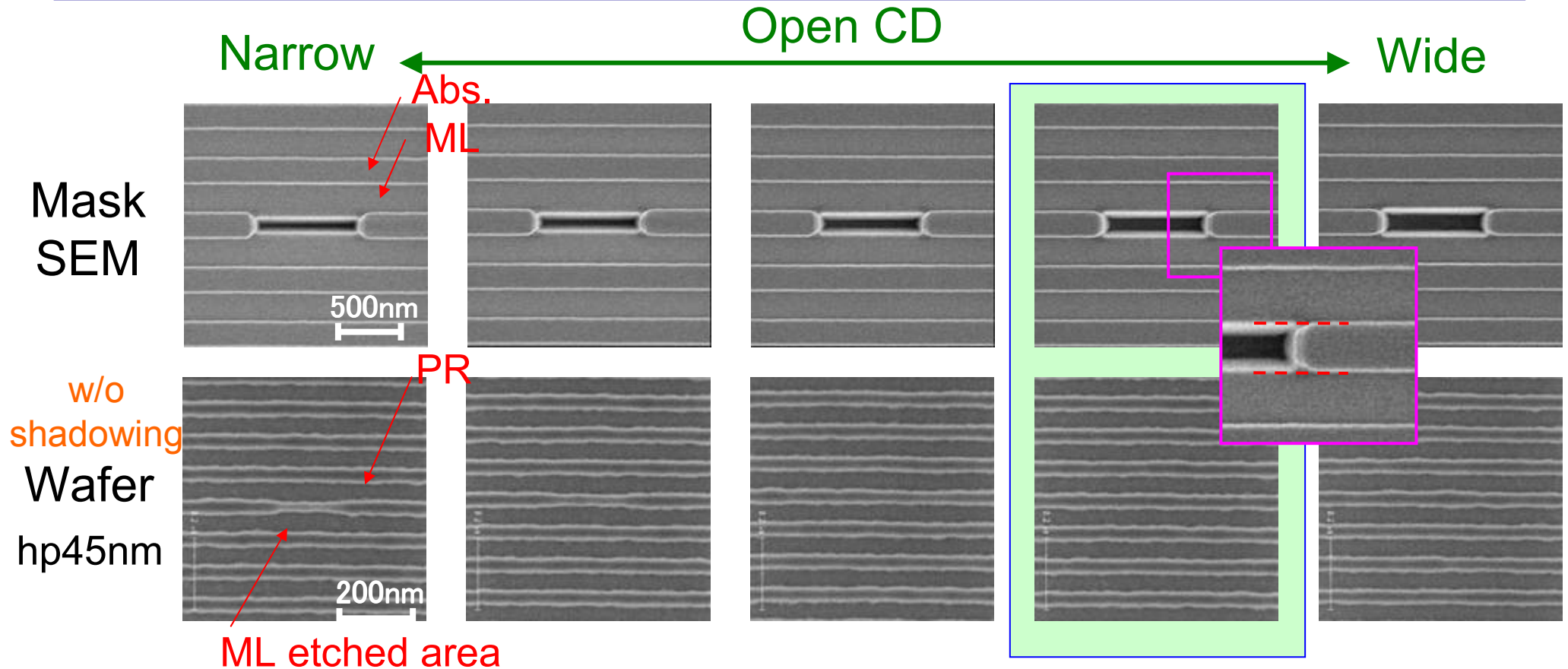
SEM top view

hp225nm L/S



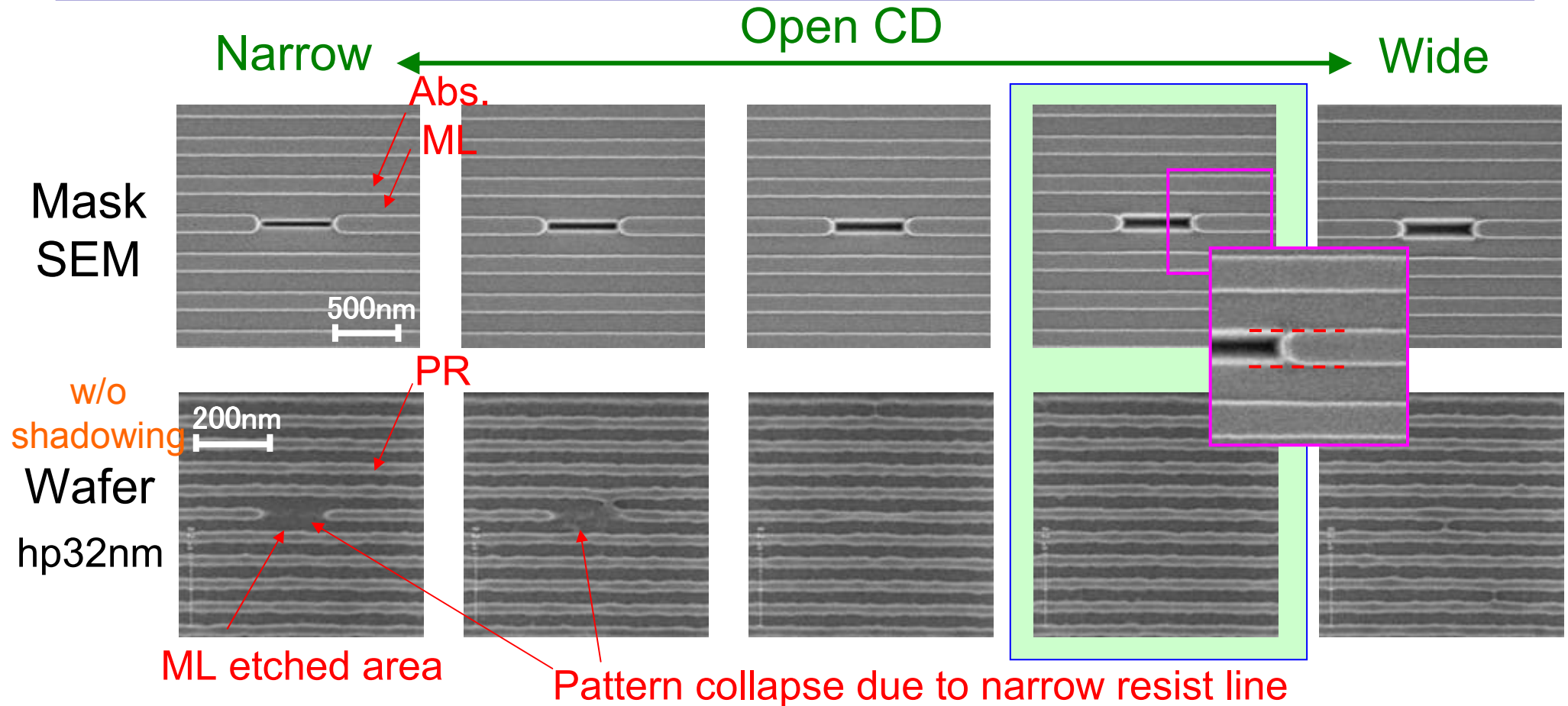
TEM image





SFET exposure results showed that ;

- the ML etched area behaved as low reflection area
- the printed CDs were proportional to the ML open CDs
- the best performance was obtained to fit the ML open CD to the absorber CD

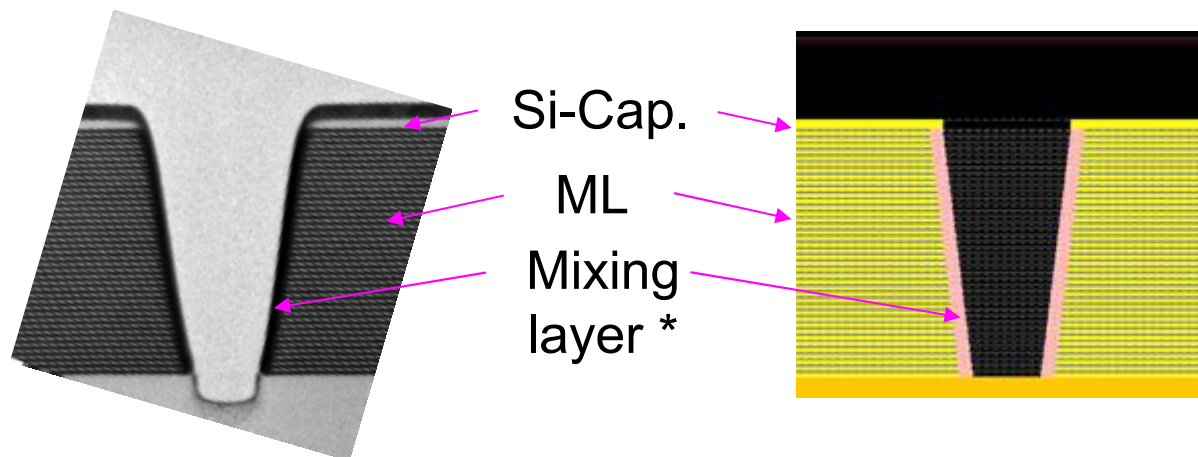


The exposure result showed the same tendency of hp45nm.
 - the best performance was obtained to fit the ML open CD to the absorber CD

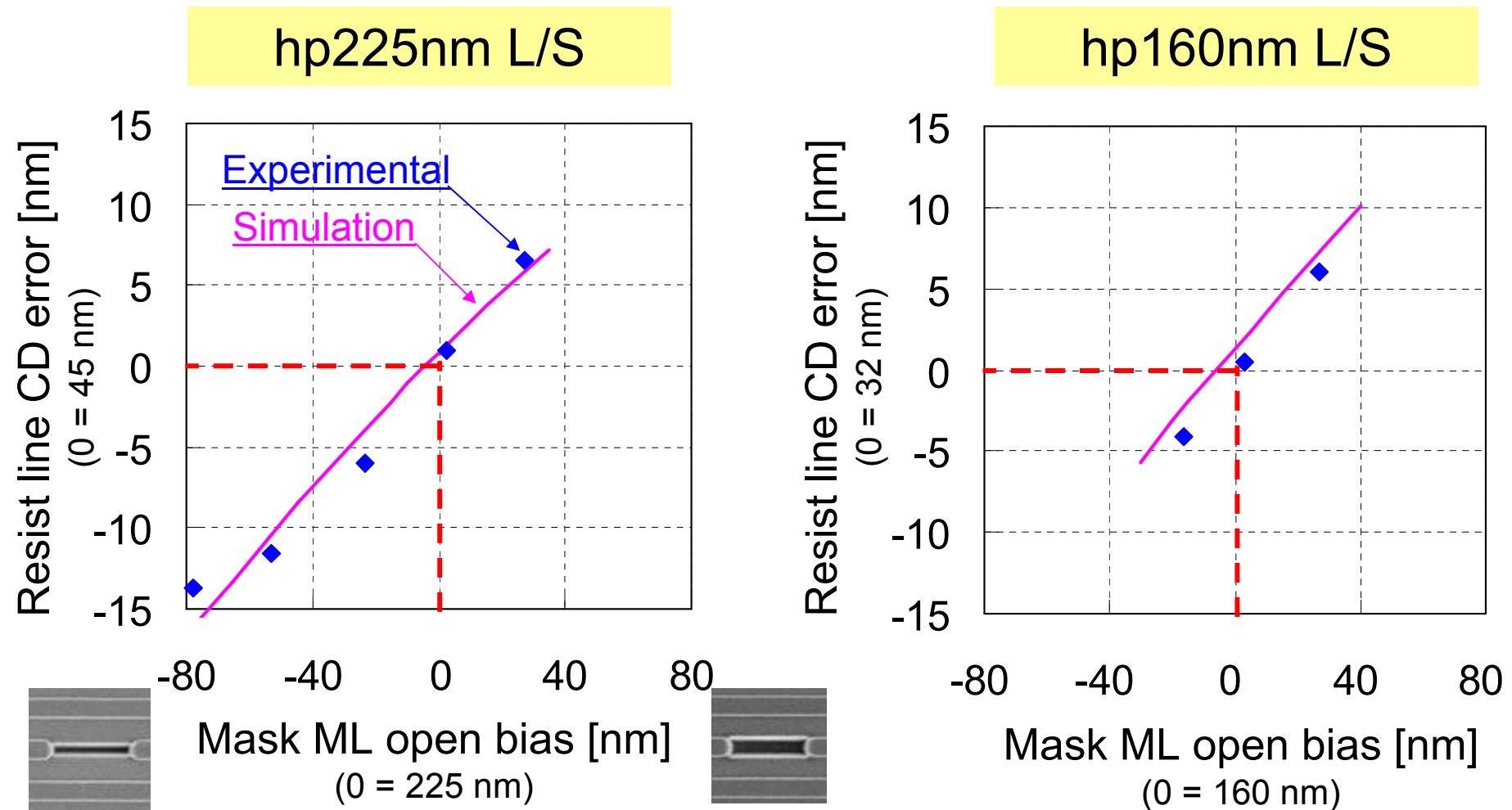
Simulator:	EM-Suite TM (Panoramic Technology)
Exposure condition:	Same condition as SFET
CD calculation:	Threshold method

TEM image

Simulation Model



* n, k values were calculated from the optical index of Si and Mo

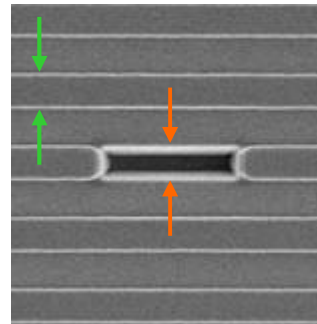


- Simulation model and results agree well with the experimental results.
- The resist line CDs are slightly larger than the one-fifth of ML open CD.

Mask design : hp225nm L/S

Abs. line CD = 224.7 nm

ML open CD = 227.3nm



Wafer printed images

Focus

-50 nm

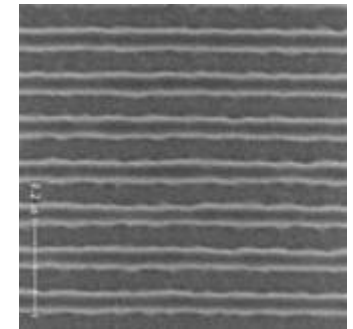
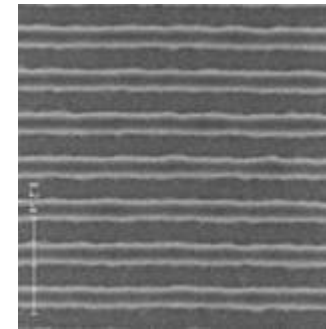
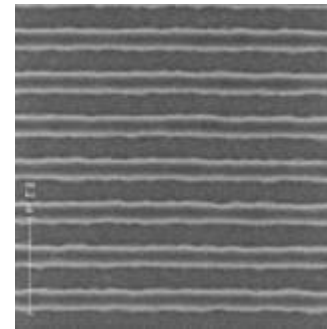
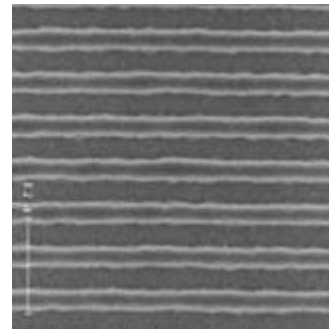
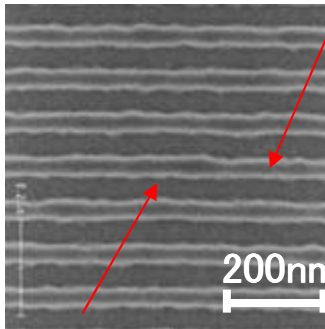
PR

-25 nm

-0 nm

+25 nm

+50 nm

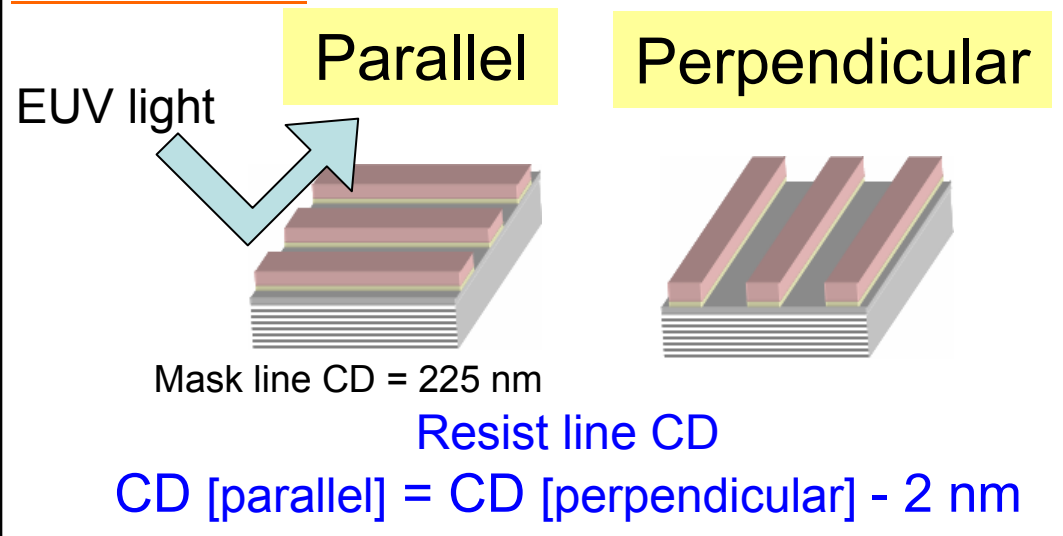


ML etched area

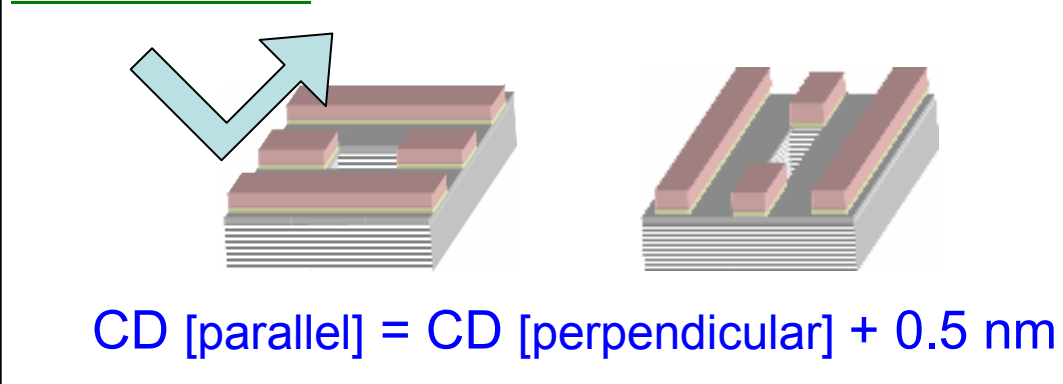
Reference	46.0 nm	45.5 nm	45.9 nm	46.0 nm	45.1 nm
Repaired	47.0 nm	46.4 nm	45.5 nm	47.2 nm	46.9 nm

The defocus characteristic was excellent, larger than 50 nm.

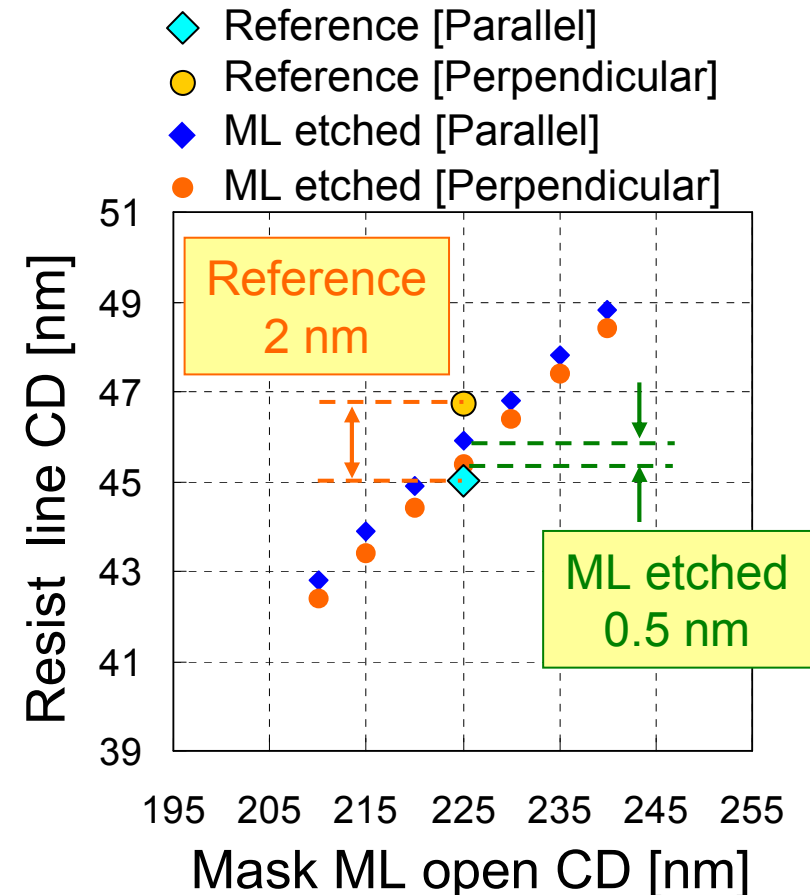
Reference



ML etched



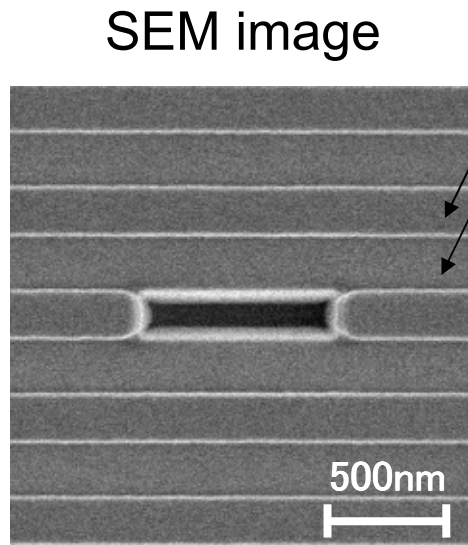
Mask ML open CD vs. printed CD



The ML etching method will be requires its repair be done under the consideration of the shadowing effect.

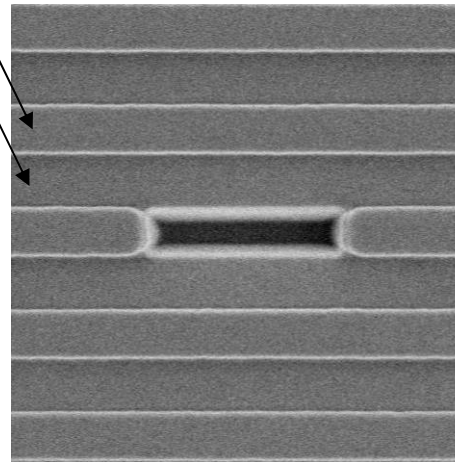
Cleaning process
(APM=> Rinse=> Dry) x 5 cycles

Pre cleaning process

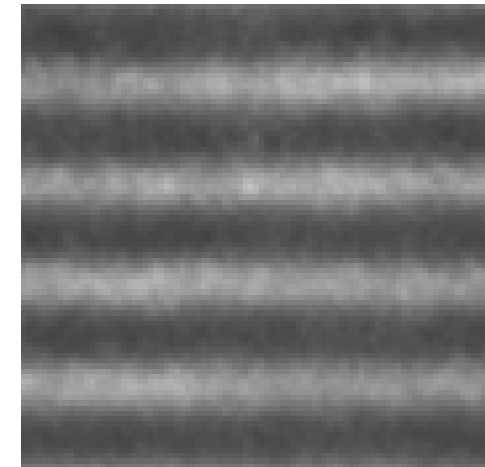


Abs.
Si-cap.

SEM image



EUV microscope*
image



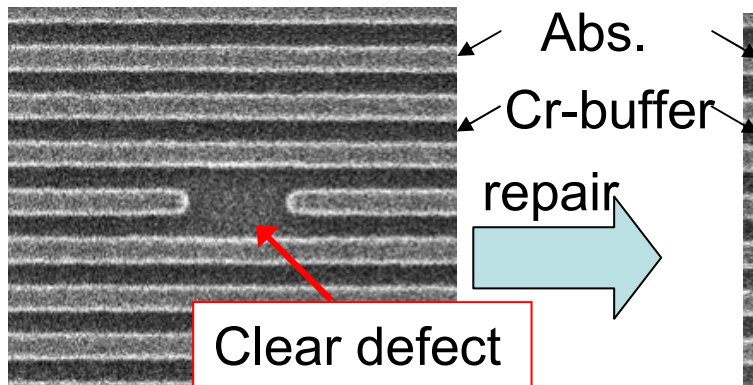
No cleaning damage was observed.

* **Center for EUV Lithography, LASTI, University of Hyogo**

“Actinic Mask Inspection using an Extreme Ultraviolet Microscope” K. Takase et al., Proc. SPIE Vol. 7379 (2009).

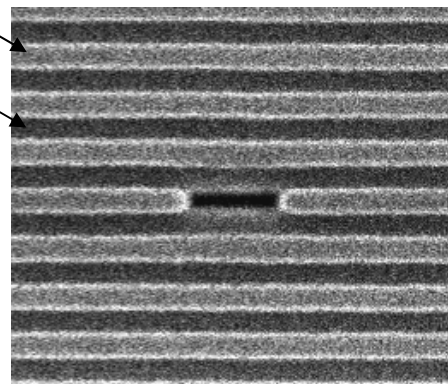
Pre repair

SIM image (SIR-7)



Post repair

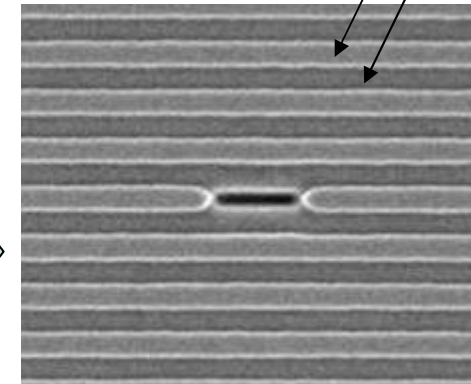
SIM image



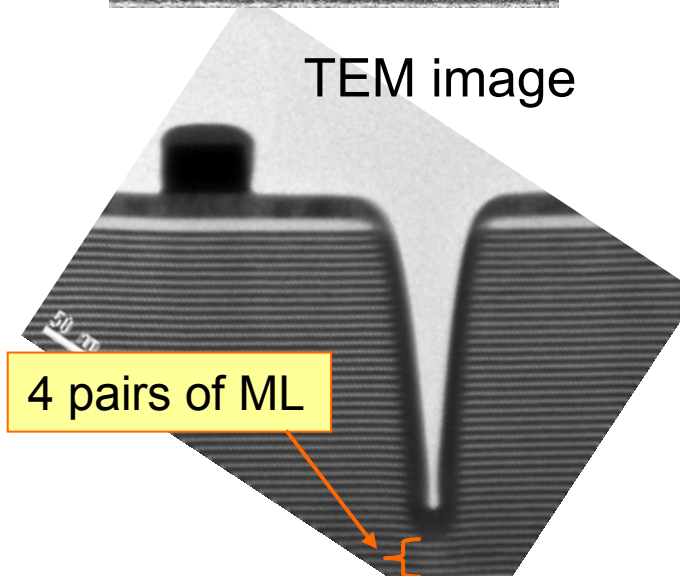
Buffer
etching

SEM image

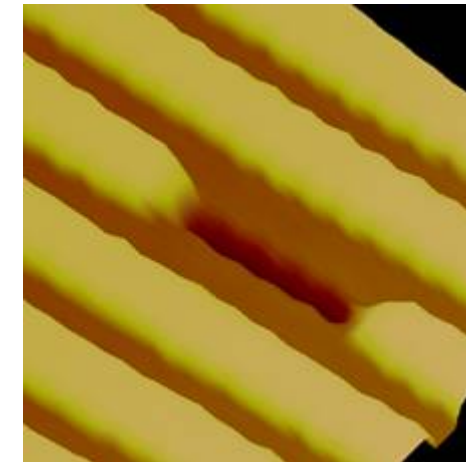
Abs.
Si-cap.



TEM image



AFM image



FIB technique has extendibility for hp88nm L/S pattern

ML etching performance

- ✓ The ML underlying the line-cut defects were successfully removed by FIB physical etching process.
- ✓ The sidewall angle was 83 degree and the thickness of the mixing layer was about 15 nm.

Wafer printing performance

- ✓ The wafer printed CDs were proportional to the ML etched CDs.
- ✓ The printing performance of ML etched pattern was not sensitive to focus error.
- ✓ The shadowing effect of the ML etched pattern was estimated to be smaller than that of the absorber pattern.

Acknowledgement

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